

DIPLOCARDIA HULBERTI AND *D. RUGOSA*, NEW
EARTHWORMS (ANNELIDA: OLIGOCHAETA:
MEGASCOLECIDAE) FROM KANSAS

Samuel W. James

Abstract.—Two species of the megascolecoid earthworm genus *Diplocardia* (subfamily Acanthodrilinae) are described from collections made in tallgrass prairie in north-central Kansas. *Diplocardia hulberti* has similarities to *D. meansi* and some undescribed material in Gates (1977), while *D. rugosa* appears to be closely related to *D. smithii*.

Studies of earthworms in tallgrass prairie of the Flint Hills region of Kansas resulted in the collection of two species of *Diplocardia* that appear to be unlike any previously described members of the genus. Both species were found on the Konza Prairie Research Natural Area (KPRNA) in Geary and Riley counties, a large tract of tallgrass prairie maintained by The Nature Conservancy and Kansas State University for research. Apart from riparian forests, vegetation is dominated by the grasses *Andropogon gerardii* Vitman, *A. scoparius* Michx., *Panicum virgatum* L., and *Sorghastrum nutans* L. Soils are silty clay loams and silty clays of the Florence-Benfield series. Mean annual precipitation is 82 cm, but the region is prone to drought and temperature extremes. Consequently earthworm activity is greatest in the spring and fall, though the *Diplocardias* may remain active all summer if rainfall is sufficient.

The species described below were determined to be new on the basis of Gates (1977). I did not check any museum collections for previously undetected individuals of these species. The following descriptions are based on observations of five clitellate individuals per species. Dissected holotypes and undissected paratypes have been deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM).

Jamieson (1978) has summarized the controversy over the assignment of family rank to the Acanthodrilinae. I have chosen to follow the classification of Jamieson (1978) and Brinkhurst & Jamieson (1971), pending further developments in this area.

Diplocardia hulberti, new species
Figs. 1A, 2A, B

Description.—External characteristics: 32–50 by 1.3–2.1 mm, width at segment xxx, body cylindrical in cross section throughout, widest point at segments vii–viii, narrowing slightly before the clitellum; segments 91, 98, 99, 100, 106. Setae closely paired throughout, conspicuous as black dots in fixed specimens; setal formula $AA:AB:BC:CD = 5:1.7:4:2$. Prostomium tanylobous to nearly tanylobous, segments bianulate in viii–xii, triannulate after clitellum. Epidermis and body wall unpigmented but may appear grayish due to presence of dark pigment on peritoneum and septa in segments ix–xii. When alive and when preserved, worm has curdled appearance in head and tail regions, due to small white inclusions in body wall. Alive, annular clitellum bright yellow; preserved, orange-brown. Nephridiopores not found. First dorsal pore at 6/7 or 7/8, to within a few segments of end.

Spermathecal pores on small protrusions

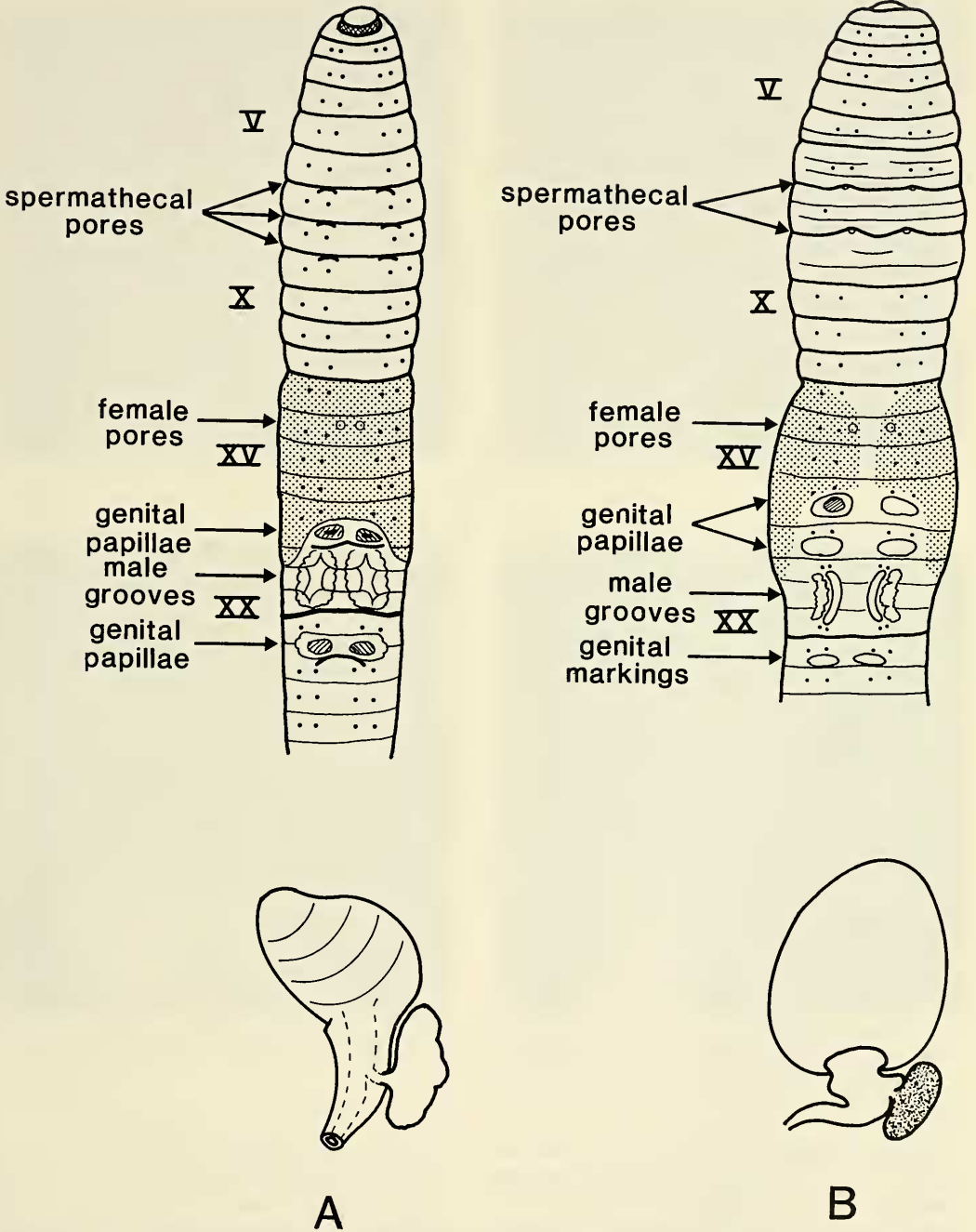


Fig. 1. A, *Diplocardia hulterti*, ventral view and spermatheca; B, *Diplocardia rugosa*, ventral view and spermatheca.

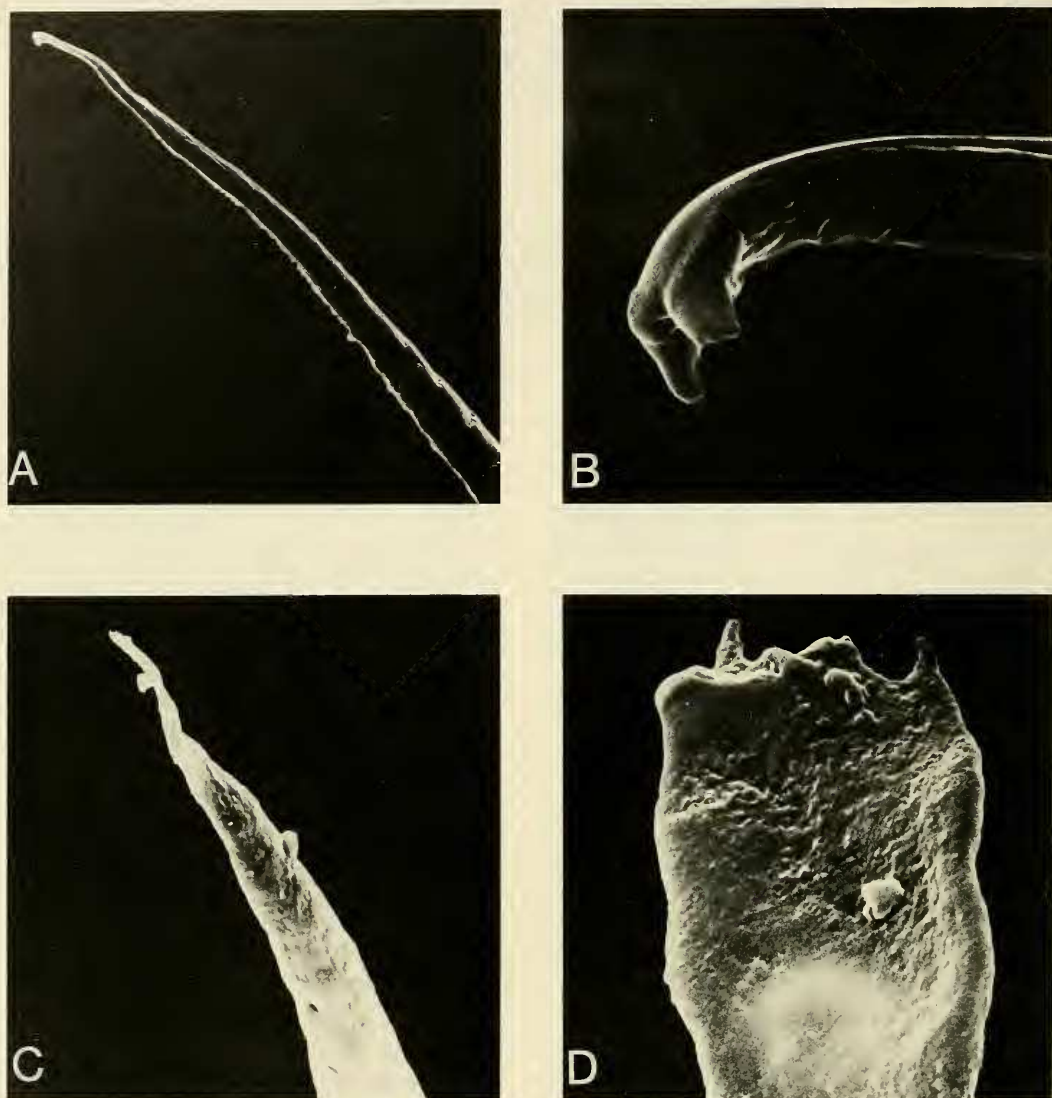


Fig. 2. *Diplocardia hulpterti*, penial setae from segment xx: A, Shaft (1500 \times); B, Tip (16,000 \times). *Diplocardia rugosa*, penial seta from segment xx: C, Shaft (2500 \times); D, Tip (16,000 \times). Irregular lumps in C and D are debris.

at leading edges of segments vii–ix, just lateral to setae *a*. Ovipores in xiii, presetal and median to setae *a* in small oval area faintly lighter than surrounding clitellar development. Genital markings paired, postsetal in xvii, centered on line of setae *A*, and paired on furrow 21/22, on or slightly median to line *A*. Male grooves from xviii–xx, straight to slightly curved, concavity facing laterally, grooves within thickened raised area. Fur-

rows 17/18 and 20/21 typically very deep on ventral side (see Fig. 1).

Setae in spermathecal and adjacent segments not modified; ambulatory setae sigmoid and unornamented. Penial setae (Fig. 2A, B) 800 \times 10 microns, sigmoid, distal quarter slightly ornamented except on narrow distal portion. Tips bifurcate and forming small hooks.

Internal characteristics: Septa 6/7–10/11

heavily muscled, in 11/12–13/14 musculature decreases to typical scant amount. Transeptal muscles in vii to xii, post-septal in vii to body wall in viii, etc.; these muscles at middorsal and laterally. Black pigment granules on septa 9/10–12/13, sometimes on peritoneum and blood vessels in intervening segments.

Alimentary canal containing 2 gizzards (v and vi) distinctly divided at septum 5/6. Esophagous smooth externally, without pouches or extramural calciferous glands, internal texture consisting of low knobs in anterior part, changing to low longitudinal folds, best developed at intersegmental boundaries, in segments xiv–xvi. Calciferous lamellae lacking. Glandular mass on dorsal side of esophagous in xiv; small iridescent glands at middorsal on esophagous in vii–ix, paired lateral glands of similar appearance in vii and viii. Intestinal origin in xvii. Intestinal constriction present at 20/21; villous internal texture persisting to end of typhlosole. Blood sinuses present in segments xvii–xxv; at most septal constrictions a blood vessel visible in longitudinal section. Simple lamelliform typhlosole less than one-third of lumen diameter arising in xix or xx, becoming rudimentary and vanishing by xl–xlv.

Nephridia 2 per segment, without bladder, extending from setal follicles of *A* to near *D*, duct to external nephridiopore at level of and slightly anterior to *D*. Anterior to intestine, tubule coiling resulting in complicated globular form; from xvii posteriorly tubule forms 2 or 3 loops flattened against body wall.

Vascular system consisting of subintestinal trunk with connections to septa, nephridia, and body wall, these collecting to large, chloragogen covered lateral vessels connecting to similarly covered and single dorsal vessel. Small vessels arising from subintestinal going to intestinal wall; dorsally, small vessels connecting intestinal circulation to dorsal vessel. Dorsal vessel continuing forwards onto pharynx, where it divides in iii and descends to ventral vessel.

Supra-esophageal vessel ix–xii, where it dives into esophageal wall. Extra-esophageal vessels v to xii; in xiii, diverging to body wall and branching repeatedly as they supply clitellar region. These fine vessels appearing to extend no farther than xvii. Commissures vi–xii, in vi oriented ventrally-anteriorly, connecting to extra-esophageal vessel and ventral vessel; commissures of vii and viii lateral, those of ix–xii having single valve each and lateral-esophageal.

First 2 segmental nerves of a side emerging separately from ventral nerve cord and partly fusing together. Ventral nerve cord bifurcating in iii to join above pharynx.

Body wall longitudinal musculature interrupted by setal follicles, latter lens-shaped and conspicuous.

Male sexual system reduced; no coagulum (developing sperm) and no testes found in x, xi; funnels in x, xi, not iridescent. Seminal vesicles preseptal in ix, postseptal in xii, divided into many lobes, gray to darkly pigmented, often reaching only to mid-lateral, that of ix larger than vesicle of xii. Prostates 0.6×0.8 mm, confined to xviii and xx, or reaching into next segment anterior, nearly completely covered by intestine. Prostatic ducts half length of gland or shorter, without muscular sheen, with one or two short kinks or coils, meeting body wall at *B*, behind septa 17/18, 19/20. Penisetal muscle bundles meeting body wall near duct. Numerous transverse muscle bands in prostatic region. Vasa deferentia meeting just posterior to 11/12, running side-by-side under peritoneum to xviii, where they dive into body wall near prostatic ducts.

Ovaries in xiii, consisting of tight clusters of short strings bearing few eggs each, whole appearing like cluster of grapes, sometimes with black pigmentation. Ovarian funnels at anterior face of 13/14, open end gently folded, with flap curved down over opening. Spermathecae (Fig. 1) in vii–ix, duct shorter than ampulla, diverticulum on lateral face of duct, attached at its middle by short stalk, or sessile in appearance but only attached at middle, diverticulum ovate, undivided.

Spermathecae erect in segments, generally with ampullae tucked under esophagous and diverticula adjacent to body wall.

Holotype: 250 m west of stone house, Irwin silty clay, Konza Prairie Research Natural Area, Riley Co. Kansas; 22 May 1981, Samuel W. James, USNM 101808.

Paratypes (4): 250 m west of stone house, Irwin silty clay, Konza Prairie Research Natural Area, Riley Co. Kansas; 22 May 1981, Samuel W. James, USNM 101809.

Ingesta, parasites: Mineral soil, fine root fragments and what is apparently grass leaf litter made up the bulk of ingesta. One 3 mm long nematode was found in the gut of one specimen.

Remarks.—The above description is based on specimens taken from the type locality. Other specimens have been found in the same soil type (Irwin silty clay loam), but not in other soils, on other sites in KPRNA, some of which are in Geary County. A single specimen with strong affinities to the KPRNA worms was found in the author's lawn at 1726 Colorado St. Manhattan, Kansas, also Riley County. However, until more specimens can be obtained, it seemed best to omit it from the present description. The reasons are as follows: it had genital markings at 15/16 and 16/17, segments x and xi were filled with coagulum, the spermathecal duct was more sharply differentiated from the ampulla, its first dorsal pore was at 9/10, and the arrangement of segmental nerves arising from the ventral nerve cord was markedly different, the anteriormost nerve single, and a pair arising posteriorly and remaining separate. The collection site is separated from KPRNA by 12 kilometers and a large river; hence the possibility of subspecific variation needs attention.

Diplocardia hulberti is apparently male-sterile and presumably parthenogenetic. No iridescence was detected on any diverticulum or sperm funnel examined, and all specimens were fully clitellate.

Behaviorally this species is distinct from

most members of the genus found on KPRNA in that it actively flees when in hand. The others become semi-rigid and may excrete a little coelomic fluid, except *D. prosenderis*, which flees and oozes. The active nature of *D. hulberti* and presence of leaf litter in the gut suggest that it is active at or near the soil surface. *Diplocardia hulberti* is named in honor of the late Lloyd C. Hulbert, whose enthusiasm led to the establishment of KPRNA and consequently to the author's choice of research site. He is therefore partly responsible for the discovery of this worm.

Affinities.—In Gates' (1977) key, the characters of *D. hulberti* lead to the couplet containing *D. meansi* Gates and an undescribed species, *D. sp. II*. It can be distinguished from both these by size and number of segments (smaller in each case), and from *D. sp. II* by its smaller, ovate prostates, the dark internal pigmentation, hooked tips of the penial setae, and the clear locations of the spermathecal pores. *Diplocardia hulberti* is the smallest sixthelal *Diplocardia* known. The following combination of characters will distinguish *D. hulberti* from all other known members of the genus: three pairs of spermathecae, dorsal blood vessel single throughout, last hearts in xii, prostomium tanylobous, abundant pigment granules on septa and vascular system in pre-clitellar segments, annular clitellum, spermathecal diverticulum sessile or with very short slender stalk, spermathecal duct without a crypt, tips of penial setae hooked.

Diplocardia rugosa, new species
Figs. 1B, 2C, D

Description.—External characteristics: 30–45 × 2 mm, width at segment xxx, body cylindrical throughout, widest at clitellum and nearly as wide in spermathecal segments. Segments 112, 113, 113, 122, 130, biannulate in vi, triannulate vii-end. Prostomium tanylobous and smooth; periproct smooth, anus a vertically oriented lenticular

opening. Setae closely paired throughout, $AA:AB:BC:CD = 16:3:14:4$, $DD < \frac{1}{2}$ circumference. Setae frequently missing or displaced in segments vii–x, xix, xx. Body unpigmented, color when live pink to gray, pale gray with brown clitellum when preserved. Nephridiopores at *D*, only found anterior to clitellum. First dorsal pore at 8/9 or 9/10, dorsal pores extending to tail.

Spermathecal pores at *A* on tips of prominent, forward leaning protuberances, high points of ridges which make up leading edges of segments viii and ix. Posterior $\frac{2}{3}$ of ix and anterior $\frac{2}{3}$ of x broad and smooth. Ovipores presetal and median to *a* in xiv, enclosed in faint oval area. Clitellar development lacking along narrow strip at midventral, roughly equal in width to spacing between setae *A* and *B*. Genital markings paired and postsetal, centered on *AB* in xvi, xvii, and xxi. Extra unpaired genital markings have been seen in xv. Epidermis thickened in area bounded by genital markings and male field, with deep furrows adjacent to genital markings. Male grooves having thickened ridges lateral to them; grooves curved with concave side facing laterally (Fig. 1); grooves extending from equator of xviii to first third of xx. Penial setae visible in close pairs at ends of grooves, just inside line of setae *A*.

Setae in spermathecal and adjacent segments unmodified, may be missing. Ambulatory setae 160×13 microns, sigmoid, unornamented. Penial setae 350×10 microns, tip flattened, shaft slightly sculpted (Fig. 2C, D).

Internal characteristics: Septum 6/7 having light musculature, 7/8, 8/9 heavy, musculature decreasing to few radial strands in 12/13, 13/14. Trans-septal muscles 4 per segment in vii–xiii, those in vii attached to posterior face of 6/7 near gut and to body wall in viii, rest following this pattern.

Gizzards in v, vi, with distinct division but no constriction between them. Esophagus lacking calciferous lamellae and extramural calciferous glands, internal texture

pebble-grained, low longitudinal folds found only at segmental boundaries. Coagulated glandular(?) material on dorsal face of esophagus in xiv, xv, pairs of small iridescent glands on dorsal face in vii, viii, and sometimes ix. Intestinal origin in xvii; its internal texture villous with numerous lateral folds in segments xvii–xxi, after which villousness and lateral folding decreasing. Blood sinuses present to xxv. A simple lamelliform typhlosole begins in xix and ends in 1.

Nephridia 2 per segment, without bladder, attached to septa near setae *B*, extending to *D*, where tubules join body wall. In segments anterior to intestine, nephridia complexly looped and coiled into globular shapes, while in intestinal segments, tubule makes single descending loop and turns upwards into a coil. These latter nephridia flattened against body wall.

Dorsal vessel single throughout, breaking into small descending vessels in iii. In intestinal segments, having chloragogen on its lateral edges. Subintestinal trunk supplying blood to intestine via short vessels, and to body wall and nephridia via single pair of segmental vessels per segment. Lateral vessel takes blood from these parts to dorsal vessel. Intestinal circulation completed by 2 connections per segment to dorsal vessel. Segmental vessels in clitellar region larger than elsewhere. Supra-esophageal vessel from ix to xiii, where it dives into esophageal wall; extra-esophageals from v to xiii, where they diverge to body wall and branch out through clitellar segments. In v and vi, extra-esophageals send two vessels per segment to ventral vessel. Hearts in ix–xii, lateral-esophageal. Commissures in v–viii, connecting dorsal vessel to ventral.

Anterior segmental nerve on a side of ventral nerve cord separated by some distance from second and third nerves, which emerge adjacent to each other and run separately to body wall.

Testes and funnels free in x, xi, with coelomic cavities of these segments filled with

coagulum. Funnels highly iridescent and ovate with wavy edges. Seminal vesicles of xii larger than those of ix, all divided into numerous irregular lobes. Vasa deferentia originating at base of each funnel and running side-by-side from xii under peritoneum to insertion of prostatic duct of xviii. Flattened tubular prostates 0.4×3 mm, completely surrounding intestine in segments xix–xxii, may extend into xvii, xxiii. Prostatic ducts short (0.6 mm), straight, lacking muscular sheen; meeting body wall postseptally in xviii, xx next to penisetal follicles. Penisetal follicles short finger-like projections with long strand of muscle extending from proximal tip diagonally back to body wall. Numerous transverse muscle bands in prostatic segments.

Ovaries in xiii, consisting of several strings emanating from ventral insertion of 12/13. Each of these strings dividing to form sub-cluster with many short strings of ova. Ovarian funnels in xiii, trumpet-shaped in cross section. Tubular part of funnel extending through 13/14 to body wall. Spermathecae (Fig. 1) consisting of broad ampulla attached to thick, sigmoid duct. On lateral face of duct, ovate diverticulum attached at its middle by short stalk. Some diverticula iridescent, no apparent internal divisions. Spermathecal orientation variable, sometimes erect and wrapped around esophagus, and others aimed posteriorly under esophagus.

Holotype.—Approximately 1 km east of west boundary of KPRNA, just south of Riley Co. line, in Geary Co., Kansas; thin, rocky soils of ridgetops under tallgrass prairie; 29 May 1981, Samuel W. James, USNM 101810.

Paratypes (4).—Approximately 1 km east of west boundary of KPRNA, just south of Riley Co. line, in Geary Co., Kansas; thin, rocky soils of ridgetops under tallgrass prairie; 29 May 1981, Samuel W. James, USNM 101811.

Remarks.—Specimens were taken from shallow, rocky soils (Florence silt loam) on

ridgetops in the portion of KPRNA in Geary county. To date, *D. rugosa* is known to occur only in the higher ground. It and *D. smithii* McNab & McKey-Fender make up the bulk of native earthworm biomass in upland sites of KPRNA, where both are abundant. Specimens have also been found in upland prairie 8 kilometers south of Manhattan, Kansas, just east of Kansas highway 177 on KPRNA, in Riley County.

The epithet reflects the appearance given the worm by the ridges and protuberances associated with the spermathecal pores.

Affinities.—Regarding the clitellum as saddle-shaped, *D. rugosa* arrives at couplet 12 in Gates (1977), where it is seemingly his “sp. I.” Gates’ sp. I does not greatly resemble *D. rugosa* in the few characters given in Gates (1977), and it was collected in the Ouachita National Forest of Arkansas. Therefore I do not consider the two to be one species. Gates considers his sp. I to be very similar to *D. smithii*. Differences between *D. rugosa* and *D. smithii* include the larger size of the latter, characters of the penial setae, the prostomium, location of first dorsal pore, structure of the spermathecae, and openings of the spermathecal pores.

If the clitellum be considered annular, *D. rugosa* keys to *D. invecta* Gates, previously described from unknown locations in Texas and Mexico (Gates 1955, 1977). However, differences in penial setae, prostatic ducts, genital markings, and spermathecae prevent union of the two groups.

The following combination of characters is unique to *D. rugosa* among known members of the genus: last hearts in xii, no califerous lamellae, quadrithecal with non-cryptate spermathecal ducts, spermathecal diverticulum attached by a short stalk, saddle-shaped clitellum, tanylobous prostomium, and intestinal origin in xvii.

Acknowledgments

The author thanks Edward Easton of the British Museum (Natural History) for in-

valuable assistance in the early stages of his study of the anatomy of *Diplocardias*, and William Fender for helpful suggestions on technique. Ted Barkley and Henry D. Blocker reviewed an early version of the manuscript.

Literature Cited

- Brinkhurst, R. O., & B. G. M. Jamieson. 1971. Aquatic Oligochaeta of the World. Oliver and Boyd, London, Toronto, 860 pp.
- Gates, G. E. 1955. Notes on several species of the earthworm genus *Diplocardia* Garman.—Bulletin of the Museum of Comparative Zoology, Harvard 113:230–259.
- . 1977. More on the earthworm genus *Diplocardia*.—Megadrilogica 3:1–47.
- Jamieson, B. G. M. 1978. Phylogenetic and phenetic systematics of the opisthoporous Oligochaeta (Annelida: Clitellata).—Evolutionary Theory 3: 195–233.

Department of Biology, Maharishi International University, Fairfield, Iowa 52556.